ISSUES IN AFLOAT COMMAND CONTROL: THE COMPUTER-COMMANDER INTERFACE

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THESIS

ISSUES IN AFLOAT COMMAND CONTROL:

THE COMPUTER-COMMANDER INTERFACE

by

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This thesis examines afloat command control with emphasis on the computer-Commander interface. Emphasis is placed on command displays found in Combat Information Centers and on the bridge. The configuration and development strategy for these two areas on SPRUANCE class destroyers are examined in some detail. The planned Aegis Combat System is also discussed from the command control point of view. Several issues in afloat command control

20. (continued)

are discussed including 1) Role of the afloat Commander and "President-to-Foxhole" communications, 2) Location of the afloat Commander in a crises, 3) Manual backup to computerized command control systems, and 4) The Commander-Computer interface.

Issues in Afloat Command Control:

The Computer-Commander Interface

by

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This thesis examines afloat command control with emphasis on the computer-Commander interface. Emphasis is placed on command displays found in Combat Information Centers and on the bridge. The configuration and development strategy for these two areas on SPRUANCE class destroyers are examined in some detail. The planned Aegis Combat System is also discussed from the command control point of view. Several issues in afloat command control are discussed including 1) Role of the afloat Commander and "President-to-Foxhole" communications, 2) Location of the afloat Commander in a crises, 3) Manual backup to computerized command control systems, and 4) The Commander-Computer interface.

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ACRONYMS

AAW - Anti Air Warfare

AEGIS - A combat support system. Also refers to a new class of ships which will be equipped with AEGIS, the AEGIS destroyer. (AEGIS is not an acronym; in Greek mythology it was the shield of Zeus.)

APL - Applied Physics Laboratory (Johns Hopkins University)

ASROC - Anti Submarine Rocket

ASMS - Advanced Surface Missile System

ASTAB - Automated Status Board

ASW - Anti Submarine Warfare

ATDS - Airborne Tactical Data System

BPDSMS - Basic Point Defense Surface Missile System

CDS - Command and Decision System (Aegis)

CDSS - Command and Decision Subsystem (SPRUANCE)

CIC - Combat Information Center

CIWS - Close In Weapon System

CNO - Chief of Naval Operations

CRT - Cathode Ray Tube

DD - Destroyer (a ship type)

DDG - Guided Missile Destroyer (a ship type)

DRT - Dead Reckoning Tracer

EW - Electronic Warfare

GFCS - Gun Fire Control System

GMFCS - Guided Missile Fire Control System

LAMPS - Light Airborne Multi-Purpose System (a helicopter)

LSD - Large Screen Display

MPDS - Message Processing and Distribution System

MTDS - Marine Tactical Data System

NATO - North Atlantic Treaty Organization

NSSMS - NATO SEASPARROW Missile System

NTDS - Naval Tactical Data System

OSC - Operations Summary Console

OOD - Officer of the Deck

RPM - Revolutions Per Minute

R/T - Radio Tactical (a communication circuit)

SOP - Ship Operational Program

SSW - Surface-to-Surface Warfare

TAO - Tactical Action Officer

TCM - Tactical Command Module

USS - United States Ship

WC - Weapons Coordinator

WSAP - Weapons Status/Approval Panel

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I. INTRODUCTION

A. COMMAND CONTROL AFLOAT

Command control has many definitions. JCS Pub 1 defines it as "the exercise of authority and direction by a properly designated commander over assigned forces in the accomplishment of his mission." It goes on to define a command and control system to be "the facilities, equipment, communications, procedures and personnel essential to a commander for planning, directing, and controlling the operations of assigned forces pursuant to the mission assigned." This thesis does not presume to examine all aspects of command control afloat but instead concentrates on one small portion of it: the computer to Commander interface. It will examine some of the existing afloat command control capabilities, operational concepts, and technology. By studying the "computer to Commander" interface, this thesis will examine how best to present information to the Commander in a readily digestible format.

It is important to note that command control is a tool of the Commander. If "command control" facilities, procedures, etc., are the tool of someone else, they are not "command control." Thus this thesis will not discuss operator display requirements unless the Commander IS the operator. This thesis will not differentiate between "command control" and "combat direction," which can be loosely defined as the management of specific weapons; the distinction between these two operational phases is practically nonexistent for the afloat Commander.

This thesis assumes that the means are available to sense the environment and to gather this data for the Commander; assumes that once he has this data he interprets it; arrives at decisions, and is able to implement those decisions. This thesis therefore will not examine the telecommunications process or any computer attributes other than those features which transfer data to the Commander.

This thesis contains a bit of the history of afloat command control displays, an examination of some present and future systems, and a review of some of the controversies concerning the computer-Commander interface. Some of this information, as well as most of the opinions that are presented, was obtained from guest lecturers and from informal discussions held with Navy personnel in Monterey, San Diego, and Washington, D.C. during the author's course of instruction at the Naval Postgraduate School. Since some of these contacts do not wish to be identified, some of this information cannot, of course, be specifically documented.

B. WHAT IS A CIC?

In 1927, in writing about the arrival of the "wireless," Frederick Harcourt Kitchin wrote (9:3-4):

> "The vast solitude of the ancient Seas has gone forever ... The disappearance of solitude, the dispersal of loneliness (came with) the coming of the Great Noise which now resounds upon the waters. It began as a soft faint whisper nearly thirty years ago. And from that thin trickle of audible signals, first heard by Senatore Marconi, has come the mighty torrent which we know today, a torrent which flows invisibly

(yet clearly to be heard) over sea and land until the world itself has become too sma.. to bound its possibilities."

The mighty torrent continued to grow. Technical advances during World War II led to the development of the modern Combat Information Center (CIC). As described by Rear Admiral Daniel V. Gallery in 1945: (8:151)

> "On the way up to the flight deck we pass the brain of the ship, the Combat Information Center. The C.I.C. is full of squawk boxes, dead-reckoning tracers, status boards, and vertical display plots. It is like a broadcasting studio, stock broker's office, bookmaking establishment, and airport control tower all rolled into one. All information flows in through C.I.C.; is evaluated and displayed there; and the orders to meet changes in the current situation are flashed out from this point."

The basic mission of the CIC has not changed much over the years despite great advances in technology. The Watch Officer's Guide states: "CIC has as its major purpose the gathering, displaying, and evaluation of data and information in order to assist the commanding officer in handling his ship. It also disseminates information." (18:81)

The computer, of course, has become an integral part of the CIC in the Navy's better equipped ships. As stated by Captain Robert E. Ammann in 1977 (1:2);

> "The environment at sea, both the external environment, which is frequently characterized by adverse states and weather, and the internal work environment, which is frequently characterized by short response times, created conditions of high stress ... Vast quantities of oral and written information (are) presented by multiple means, such as face to face spoken word, voice

> radio, telephone, visual displays, and narrative messages, creating a high "noise" environment and sensory overload. This sensory load must be processed and decisions made at a rapid pace, placing severe demands on both the short and long term (human) memory. The computer software programs can provide assistance in keeping track (of) the multiple task and alerting the ... (necessary personnel) to events requiring attention, and preventing things from "falling through the crack." The most critical task, and the point where computer assistance can be of considerable value, is during situation assessment when events are unfolding rapidly."

In short, CIC is the place with the "big picture," the place from where the Commander can keep track of his own forces in the air, on the surface, and under the surface, and can locate, identify, track, and, if necessary, destroy multi-threat enemy forces. As stated in the Watch Officer's Guide (18:81-82): "The capabilities of CIC are limited only by its equipment and the state of training of its personnel."

C. OTHER COMMAND CONTROL RELATED FUNCTIONS

1. Ship's Sensors

Ever since "the coming of that Great Noise which now resounds upon the waters" (9:3), there has been some difference of opinion between those who believe the bridge is the best location from which to observe the environment and those who believe that they can perceive more with the electronic devices which are normally located elsewhere in the ship. The idea that electronic servants can be better sensors than the human eye, even at short distances, was tragically proven on 14 April 1912. Fifteen hundred lives were lost because men relied on

their eyes instead of the radio, as shown in the following passage (9:21-35):

> "(At about eleven that night), the lights of an approaching vessel were seen on the starboard quarter. Neither the captain of the CALIFORNIAN nor his officers connected this steamer in their minds with the TITANIC. In their view the lights indicated a vessel of about their own size, and were not such as would have been emitted by a blazing sea monster. It was just about at that moment, eleven o'clock, that Evans, the wireless man in the CALIFORNIAN, came actually into touch with his opposite number in the TITANIC, and knew, from the strength of her answering signals, that she was close at hand.... (At eleven thirty, he) took-off his head 'phones and turned into his bunk .... Ten minutes later the TITANIC was ripped up by ice actually within sight of the CALIFORNIAN, though not identified by the deck officers on watch. There followed two hours and forty minutes of agony in the TITANIC, and of puzzled anxiety in the CALIFORNIAN. Meanwhile the one man who could instantly have identified the TITANIC by wireless signals, and within less than an hour have caused the CALIFORNIAN to range alongside and save all those fifteen hundred lives, continued to slumber in his bunk ....
>
> There was little to occupy the minds of either of ... (the two men on watch on the bridge of the CALIFORNIAN) except that strange vessel yonder, of which they could see one masthead light, a red side-light, and two or three small indistinct lights on deck.... (They) watched this vessel for the whole of the time she remained in sight...
>
> At two o'clock,... (the) Officer on watch, who all along had been more than a little worried, was becoming gravely uneasy. The lights of that distant steamer were looking "queer" and "unnatural." Some were being shut in and others opened out. The red side-light was observed... to be rising up, and ... there was "something funny" about it. The conclusion reached by these bewildered observers was, however, that the

vessel was steaming away from the CALIFORNIAN, and gradually disappearing to the south-west .... At twenty minutes past two all the lights had vanished. It was at this moment, twenty minutes past two, that the TITANIC sank. These two men had seen her dying calls written in rocket bursts upon the black clear sky, had watched her list and sink, and all the while were unconscious of the tremendous tragedy being played out to its end before their eyes."

Despite the inadequacies of the human eye as a sensor, and to the surprise of many who have never been to sea,(5:42):

> "The role of the lookout has changed little down through history. While it's true a lookout now has the benefit of binoculars and sound-powered phones along with radar, sonar and other electronic equipment to help him safeguard a ship, no system is infallible.
>
> A low-flying aircraft may elude radar; a submarine, with only its periscope breaking the water, could slip by sonar unnoticed; or hazards to navigation -- such as wood pilings or logs floating just beneath the water's surface -- could go undetected by electronics.
>
> Although lookouts are rarely remembered by name for their contributions to man's survival at sea, history has proven that it will take more than technological advances to replace the ever-watchful eye."

As mentioned in the previous quotation, lookouts have electronic helpers. Today's "crow's nest" lookout is electronic, not human. A sensor, man or machine, can "see" further with additional height, but the topmost positions of a ship are reserved for its various antennas. When operational, some of these antennas produce electromagnetic emissions which are potentially fatal to anyone who ventures aloft. When a ship is underway during low visibility or in congested traffic areas, Navy regulations require that at least one human

lookout be placed as far forward and as close to the water as feasible. Electronic sensors generally "report" to CIC, but reports from human lookouts go to the Officer of the Deck (OOD) on the bridge.

2. <u>Bridge</u>

The OOD, who is the officer on watch in charge of the ship, reports directly to the commanding officer for the safe navigation and general operation of the ship, and to the executive officer for carrying out the ship's routine. The OOD thus has many responsibilities, and among them is insuring that CIC is kept informed of visual bearings and fixes, lookout reports, visual signals and messages, and critical decisions made by the Captain or himself. Every qualified OOD must be knowledgeable of the purpose, capabilities, and limitations of CIC. An understanding of both stations and how they mutually support each other is important. On many ships junior officers' training includes standing watches both on the bridge and in CIC.

The OOD usually also has the conn. The term "conn" is not found in Navy Regulations, but all ship's personnel understand that the person who has the conn controls the movements of the ship. During intricate or dangerous maneuvers, the commanding officer customarily takes the conn, or at least is on the bridge to watch the overall picture and guard against mishap. The <u>Watch Officer's Guide</u> summarizes the relationship between CIC and the conn as follows (18:82):

> "A good CIC has the whole tactical picture and knows where all units are and what they are doing. With this knowledge and

the advantages of space, good lighting, and equipment, CIC is capable of providing invaluable information and advice to the conning officer. Maneuvering problems are worked out and radar fixes are obtained which permit the CIC officer to recommend courses and speeds.

Note, however, that CIC always provides information and recommendations, not decisions. CIC operates as a staff officer who is always careful to recommend a course of action to his admiral. Decisions are made by those responsible -- and the officer of the deck (or the officer who has the conn) is the one responsible.

There are exceptions to this. Control of gunfire in shore bombardment is directed from CIC. An increasing number of other operations, such as ASW (anti-submarine warfare) and AAW (anti-air warfare), are now handled from CIC; the commanding officer stations himself there and directs the OOD who conns the ship from the bridge. The fact remains that in conning the ship, CIC's function is to recommend, the bridge's function is to conn."

3. Communications

It is clearly essential that a continuous and accurate exchange of information occurs between CIC and the bridge, both for operations and for the safety of the ship. Linking the various other parts of the ship are many communications channels, including sound powered telephones, general audio alarms, and intercommunication voice units (known throughout the Navy as MC's or "squawkboxes").

Intership communications are handled in several areas of a ship. The communication center, or "radio", is the formal message center, and the majority of the ship's receivers, transmitters, and cryptographic equipment are located here. Emergency radio spaces are isolated from other radio compart-

ments. Remote control transmitting and receiving positions are located as necessary and include the bridge and CIC. The signal bridge, located in the vicinity of the aforementioned "bridge," is responsible for all visual messages including flaghoist, flashing light, and semaphore. After the Kamikazi attacks of World War II, CIC's and radio spaces were placed in less vulnerable positions, away from the bridge. In recent years, however, the disutility of having such closely related functional areas spaced far apart physically has been realized. CIC in particular is adjacent to the bridge on newer ships. Overall, the best inter- and intra-ship communications are found in a modern CIC, as will be examined in greater detail in later chapters.

Although this thesis is not examining communications in detail, it is obvious that some operational and technical understanding of communications is necessary for effective command control. It is important to note that the barriers to satisfactory communications are not just technical and fiscal but also procedural and perceptual. "Communications are out" is a frequently heard alibi when the true problem is not a paucity of men or equipment or money or good atmospheric conditions but simply a lack of training. Too often, for example, exercise plans forbid any intentional communications jamming for fear that such a realistic situation would severely hinder the exercise. A system designed to provide data, voice, or image transmissions and which is secure, jam resistant, flexible, redundant, interoperable, and even affordable would

still be limited by the procedures and perceptions of its users.

This chapter has introduced some of the basic elements which affect afloat command control operations. In order to examine these elements in more detail, the next chapter will examine in some detail the command control configuration of one particular class of ships, the SPRUANCE destroyers. Later chapters will discuss some issues in afloat command control and current plans and problems.

II. COMMAND CONTROL CONFIGURATIONS IN A CURRENT "TYPICAL" SHIP: SPRUANCE CLASS DESTROYERS

A. MISSION AND CAPABILITIES

The USS SPRUANCE, commissioned in 1975, is the lead ship of a new class of approximately thirty general purpose destroyers. This class's primary mission is anti-submarine warfare (ASW), especially within a carrier task force. The SPRUANCE Class ships can also be used very effectively for surface warfare protection and for a wide variety of other missions as well. The use of many highly automated systems and of low facility maintenance requirements reduces the manning level of these destroyers to less than three hundred people. The extensive use of modular construction techniques facilitates both initial construction and future block modernizations. With its built-in margin for growth, a SPRUANCE Class destroyer is designed to be readily adaptable to many future weapon and sensor systems during its estimated thirty year life span. The AEGIS combat system, which will be discussed further in Chapter IV, is scheduled to be utilized aboard SPRUANCE Class hulls, and such ships will become another new class, the AEGIS Destroyers. This thesis will compare the present (state of the technology) SPRUANCE and the planned (state of the art) AEGIS in order to illustrate some basic criteria used in designing afloat command control systems.

The standard SPRUANCE Class destroyer, with her four gas turbine engines, has a range of six thousand nautical miles at twenty knots, without refueling, and a maximum speed of

about thirty three knots. She is armed with 5-in./54cal. guns, torpedo tubes, and ASROC launchers. She also has or is scheduled to employ the HARPOON surface to surface missile, the NATO SEASPARROW Missile System (to counter air threats at close ranges), the PHALANX Close In Weapon System, and the TOMAHAWK Cruise Missile. The SPRUANCE also carries either an SH-3 Sea King or two SH-2 series LAMPS helicopters. The augmentation of destroyers with helicopters greatly increases the range of the ships' detection capabilities and the range of their weapons delivery. The powerful SPRUANCE is thus designed to counter air, surface, subsurface, and land targets at all ranges of interest.

B. COMBAT INFORMATION CENTER

1. Description of SPRUANCE CIC

The SPRUANCE CIC is located just below the Pilot House and bridge (to which it is connected by a ladder), just forward of the communications center, and just above the ship's data processing center and electronics shop. It includes three functional areas: 1) Sonar Control, 2) CIC Maintenance Area, and 3) CIC itself which encompasses four subfunctional areas. These areas are 1) the Command and Decision area, which is the area of most concern to this thesis, 2) the Air and Surface Tracking and Identification area, 3) the ASW Weapons Control area, and 4) the Anti Air Warfare / Surface to Surface Warfare (AAW/SSW) Weapons Control area.

In 1971, Litton Ship Systems, prime contractor for the SPRUANCE, prepared a mockup review report pursuant to the ship

construction contract. This three-part report gives insight into the iterative design process which meshed current and future equipment requirements, and will therefore be quoted extensively in this chapter. It states (12:6-1 - 6-2):

> "The Combat Information Center (CIC) is the focal point of the operations required to execute effectively the DD 963 (SPRUANCE) Class Ship assigned missions and tasks. The CIC is one of the most critical of the combat system spaces of the ship, and considerable attention has been devoted to ensuring maximum combat effectiveness with minimum manning....
>
> The CIC is the key response mechanism to command for information handling related to the tactical situation of the ship and is concerned primarily with the timely and accurate supply, evaluation and dissemination of this information. Information handling comprises five major steps:
>
> A. Gathering
>
> B. Processing
>
> C. Displaying
>
> D. Evaluating
>
> E. Disseminating information and orders....
>
> Information handling is a continuous function which ultimately gives a composite picture of a situation and enables the commanding officer to make a final evaluation, and formulate and promulgate his orders for action."

To enable the SPRUANCE to accomplish her mission, it was necessary to increase the (12:6-3)

> "Integration of the Combat System to ensure effective exercise of command and control and full use of the capabilities of individual and collective weapon systems. Based upon these considerations, a Combat System has been designed incorporating systems having the performance capability to satisfy

the mission and to counter the threats described in System Specifications. Accordingly, the Combat System of the DD 963 (SPRUANCE) Class Ship (is) defined as consisting of all sensors, weapons, data processors, and the Command and Control System required to engage the threats in an efficient and effective manner."

The report goes on to describe (12:6-3 - 6-5):

"The following aspects of the DD 963 (SPRUANCE) Class Ship Integrated Combat System:

A. The concept of integration of systems utilizing the flexibility of a centralized Command and Control System

B. The operations, functions, and capabilities of the elements comprising the Combat System

C. The rationale behind design decisions

D. The improvements and new techniques that will be applied to the Combat System to achieve the overall ship mission.

The Combat System is composed of four groups of configuration elements, each group consisting of one or more subsystems. These groups are as follows:

A. Antisubmarine warfare group

B. Antiaircraft warfare group

C. Surface warfare group

D. Electronic warfare subsystems (Proposed)

Each of the sensor and weapon configuration elements has a specific functional responsibility with respect to the overall Combat System task. The reciprocal flow of sensor and weapon data is linked by an integrated data processing system called the Command and Decision Subsystem (CDSS) of the Combat System.

The tracking requirements for the DD 963 (SPRUANCE) Class Ship stipulate that the ship be capable of maintaining local and remote tracks.... Some are utilized in manual tracking mode, some in automatic mode with computer assist.... The Weapons element on the DD 963 (SPRUANCE) Class Ship provides the weaponry consistent with the mission to counter the surface and sub-surface and air threats."

a. Key Personnel

The Senior Officer in CIC when the Commanding Officer is not present is the Evaluator, who serves as the Command Deputy. He does not normally man a console. He is supported by two principal deputies, the Weapons Coordinator and the Operations Coordinator. Their exact responsibilities will vary with different operating conditions and on different ships. Like other CIC positions, "Evaluator" is a watch assignment (often filled by the CIC Watch Officer), but the Commanding Officer may overtly assume this responsibility, in addition to overall command responsibility, for specific periods. Regardless of his location, the Commanding Officer is always the final authority and may override the Evaluator.

The Weapons Coordinator (WC) advises the Evaluator concerning effective antiair and antisurface weapon employment and is in charge of overall CDSS operations. The Naval Tactical Data System (NTDS), with which the SPRUANCE is equipped, has a dominant air defense orientation. Since the WC is responsible for the ship's AAW, he also represents the ship in the Forces Weapons Coordination network with other ships in the task force. The WC has primary responsibility for evaluation of the overall tactical situation and for supervising the effective employment

of available sensors and weapons. All of the ship's responses to task force orders pass through the WC either for his direct action or to be passed to the other deputy, the Operations Coordinator.

The Operations Coordinator advises the Evaluator concerning surface and anti-submarine tactics and is responsible to him for the surface operations of the ship and for ASW coordination, including coordination with ownship-controlled aircraft. Operating an Operations Summary Console (OSC), he controls the ship's underwater surveillance sensors and exercises primary tactical control over the ASW search and attack operations. The ASW team is able to identify and track submarines using a variety of sources and techniques, transmit these data to a number of weapons systems, and pass on data changes even after the weapons have been fired.

b. Command and Display Subsystem

The Command and Display Subsystem (CDSS) is the primary integration and control system for all sensor and weapon configuration elements comprising the total combat system of the ship. The Litton report gives a rather thorough explanation of the CDSS (12:6-5 - 6-12):

> "The Command and Control element on the DD 963 (SPRUANCE) Class Ship contains the Command and Decision Subsystem and is the means by which the component systems are efficiently coupled together or integrated to achieve maximum internal coordination and effective performance, relative to the external environment. The Command and Decision Subsystem is a combination of man and machine designed to perform the functions of decision, command and control.

"Decision is defined as arriving at conclusions after consideration of the advisory inputs/alternatives for a given situation. For the DD 963 (SPRUANCE) Class Ship, human decision is based on advisory inputs from an automated CIC featuring a standardized display system, supported by a data processing system composed of general and special purpose (fire control) computers.... By exploiting the flexibility of the men and machines of the Command and Decision Subsystem, the sensor and the weapon elements are interrelated with increased capabilities. Integration has been implemented in the DD 963 (SPRUANCE) Class Ship Combat System design by central location and commonality of design of computers and their associated software and displays, leading to reduction of manning, economy of equipment, sharing of general facilities for common functions, and automation of functions. The functional integration is more forcefully forged together by the placement of command operator positions....

To provide the Evaluator (in the absence of the captain) with an overall view of the tactical situation, a display of all available target data is presented on the Operations Summary Console (OSC).... From the simultaneous long range display of the air, surface, and subsurface picture on this console, the Evaluator obtains information he requires to judge the requirements and responsibilities of the ... ship to the force. The Evaluator ensures that the computer-based recommendations and evaluations meet the ship's goal and overrides the computer outputs when he believes the tactical situation requires such actions. Since the Evaluator is the most knowledgeable person in CIC concerning threat tactics and his position is a floating position, he may move to the rear of CIC which is primarily involved in the specific environment the ship is presently engaged in. He, therefore, assumes the ultimate responsibility for decisions made in that environment.... It is through this decision nucleus .... that the first level decisions are made (based on sensor information provided by CIC)... Operators, ... monitoring the

automatic features of their systems and manually entering track data where necessary.

The Command and Decision Subsystem consists primarily of consoles, operators, computers, computer programs and peripheral equipment that collect, correlate, and evaluate information received from various sensors and weapons in order to coordinate command (and other) functions. The console operators of the CDSS subsystem, in conjunction with the computer programs and peripheral equipment, perform the functions described as follows:

A. Display. The CDSS ship operational program (SOP), provides for the display of pertinent tactical data concerning the air, surface, and subsurface environments. Additionally, the CDSS accepts operator evaluations and requests based on this data. The display is the man/machine interface for all CDSS consoles and interrelated subsystems (ASW, GFCS, GMFCS). During normal mode of operation, the CDSS display function interrogates all general purpose CDSS consoles for actions taken by the console operators. Actions taken at these CDSS console positions are formatted and processed within the SOP. Actions taken at CDSS console positions which generate functional commands to other systems are formatted by the SOP Display function and forwarded to the system responsible for execution or response....

B. Detection and Tracking....

C. Identification....

D. Threat Evaluation....

E. Weapon Assignment....

F. Surface Operations....

G. ASW Air Control....

H. Data Link Communications. The CDSS provides communications through Link 11 and 14. Link 11 is the data link between Navy Tactical Data System (NTDS) ships, NTDS ships and Airborne Tactical Data System (ATDS) aircraft, and NTDS ships and Marine Tactical Data System (MTDS) units; Link 14 is the data link to non-NTDS ships.

I. Electronic Warfare Control....

J. Weapon Direction/Control....

K. Combat System Monitoring and Control....

Thus, a central complex of man and machine is provided in CIC for control, direction, and employment of the entire Combat System of the ship. This fully integrated, cohesive team, aided by an integrated data processing system, constitutes a complete, rapid, and modern facility for accomplishing the mission."

c. NTDS

The Naval Tactical Data System is a complex electronic computing, display, and communications system. Requiring sophisticated hardware and software, NTDS is designed to collect, process, and evaluate almost instantaneously the tactical information needed by the Commander. It is most efficient when computing a dynamic response to rapidly changing events. Therefore it is better suited to dealing with the dynamic air situation than with the more static surface and subsurface situations.

Uncorrelated data from a variety of both on and off board sensors goes into data processing equipment located on major combatant ships. Here information such as detection, location, speed, and identity of friendly, neutral, and enemy platforms is correlated. Consoles then display the tactical situation with symbolic representations of enemy targets, their classification and movements, and defensive and offensive posture of friendly platforms. The system also gives the Commander a series of alternate weapons allocation information as well as information on other decisions which must be made. When the Commander makes his decision, NTDS can be used to transmit

the necessary orders to the ship's fire control equipment or to other ships and aircraft designated to execute the order. Link 11, a computer-to-computer link between NTDS equipped ships, enables a task force to be coordinated and to operate almost as one ship. Link 11 and link 14, the teletype link to non-NTDS equipped ships (usually ships that have no computers) also provide the individual unit commanders with information on the overall tactical situation.

The first generation of "air-to-ship guided missiles" was the World War II Kamikazi aircraft. The main defense then was antiaircraft guns. Because of poor detection, classification, and coordination systems as well as poor decisions, the Navy was inflicted with significant losses. In the fifties, faced with Mach 2 capable aircraft and a developing enemy arsenal of missiles, the Navy began research into automating CIC functions to reduce reaction time in dealing with operational problems. The Lamplight Review, also called the Lamplight Study, led to the first generation NTDS.(13) In 1961, the first operational systems were placed aboard the carrier USS ORISKANY and two destroyers. A modified version was installed on two nuclear ships, the carrier USS ENTERPRISE and the cruiser USS LONG BEACH. These early systems had numerous special purpose displays, each with its own controls and necessary training. To simplify this situation the next modification included one general purpose display that could operate in twelve modes. By 1971, the fleet had 41 NTDS-equipped ships; by 1978, that number had increased to 81. In addition, the

Navy had over 70 E-2 aircraft with ATDS, which are linked directly to NTDS. Over the years, improvements have continued but some problems, especially interoperability, remain as yet unresolved. A brief examination of this issue will illustrate complications common to some other computerized afloat command control systems.

Interoperability is a major objective. For example, in the Gulf of Tonkin during the Vietnamese Conflict one basic problem which arose was that the NTDS was incompatible with the Air Force's tactical data system. The Navy couldn't differentiate between a US Air Force aircraft and an enemy "boggie." The immediate solution came from providing the Marine Corps' MTDS in Danang with an interfacing capability. Within the Navy today, an NTDS operator from a cruiser has to relearn a large part of his skills if he is transferred to an aircraft carrier. (Engineering efforts are underway to solve this.) Software modifications cannot be made simultaneously on all ships, thus creating an inevitable period of incompatibility. Necessary software modifications may inadvertently create additional complications, such as the recent change that required the SPRUANCE Class destroyers to be the center of the task force's reference grid. To understand why this created a burden, one only need remember that the carrier is generally the "center" of the task force.

Hardware "problems" are generally not technical problems -- the phenomenal growth of technology has, in general, far exceeded the speed with which the ships can absorb it.

Part of the reason for this technological gap is bureaucratic -- a conservative estimate for major system acquisition lead time is seven years. Part of the reason is fiscal -- in an era of austere defense budgets, the Navy cannot afford to throw away workable systems and equipment simply because better technology is available. (The original NTDS test equipment was aboard the ENTERPRISE approximately fifteen years.) Part of the reason is that people don't know what they want. If a dozen Commanders are asked what new command control technology they "need," they are likely to give a dozen different answers. As a result of the combination of all these factors, not all Navy ships are NTDS equipped. Technically feasible but as yet unrealized improvements to NTDS include video graphics (with geographic information such as coastlines), reliable large screen displays, and color. These issues will be discussed more later in this thesis.

d. Communications

Communications equipment within CIC varies from work station to work station but includes various interior and external communications circuits; NTDS interphone between various console positions, the Gun Control Officer, and the Captain's chair; and various remote controls. Table I includes most of the communications circuits available to the Commander in CIC. The circuits marked "B" are also available on the bridge. Those circuits that have a specific terminal for the Commander are marked "C"; those circuits available to him in the immediate command area but are dedicated to his assistants,

such as the CIC Watch Officer or the Weapons Coordinator, are marked "A"; and those circuits that are available only in other parts of CIC are marked "O". All of these circuits are in addition to the communications center's formal message traffic.

TABLE I

SPRUANCE Communication Circuits

INTERIOR COMMUNICATIONS CIRCUITS

Sound Powered Circuits - Primary

Location	Designation	Circuit
C,B	(JA)	Captain's Battle
A	(JC)	Weapon Control
A,B	(1JG)	Helicopter Control
A,B	(JL)	Lookout
0	(2JP-1) and (2JP2)	Dual Purpose Battery Controls
A,B	(8JP)	ASW Weapon Control
A	(10JP)	Guided Missile Launcher Control
A,B	(JS)	Plotters Transfer Switchboard
A,B	(1JS)	CIC Information (NTDS Circuit)
A,B	(2JS)	NTDS Coordination
A	(21JS)	Surface Search Radar
A	(22JS)	Long Range Air Search Radar
A,B	(61JS)	Sonar Information
A	(JT1) and (JT2)	Target Designation Controls
A,B	(1JV)	Maneuvering and Docking
A,B	(JW)	Ship's Control Bearing
A,B	(JX)	Radio and Signals
A	(2JZ)	Damage Control
A	(9JZ) and (10JZ)	Magazine Sprinklers and Ordnance Repair

Sound Powered Circuits - Auxiliary

C,B	(XJA)	Auxiliary Captain's Battle
A,B	(X1JV)	Auxiliary Maneuvering and Docking

Sound Powered Circuits - Supplemental

A,B	(X6J1) and (X6J2)	Electronic Service Circuits
A,B	(X6J11 thru X6J14)	NTDS Service
A,B	(X9J)	Radar Trainer
A	(X25J)	Sonar Service
A	(X43J)	Weapons Systems Service
A	(X44J)	ASROC Service

Announcing Circuits

C,B	(IMC)	General Announcing System
C,B	(21MC)	Captain's Command
C	(22MC)	Electronic Control
A,B	(29MC)	Sonar Control/Information
A	(32MC)	Weapons Control
A	(53 MC)	Ship Administration
C,B	(2CK)	NTDS Display Interphone

Other

Pneumatic Tube (also on bridge)

EXTERIOR COMMUNICATIONS CIRCUITS

C,B		Task Force/Task Group Tactical/ Warning (Pritac) (secure voice)
C,B		Task Force/Task group Tactical/ Warning (Sectac) (nonsecure voice)
C		Fleet Warning/Tactical (Fleet Common)
C,B		Land/Launch Control (nonsecure voice)
C,B		Screen/SAU Tactical (A,B,C,D) (Screen Common) (secure voice)
O		Helicopter Operations

A	Navy General Warning Net (Harbor Common)
A	TWG Control
C	Task Force/Task Group Reporting (PriCl)
C	ASW/HUK Operations (A,B,C,D)
C	ASW/HUK Operations (A,B,C,D) (Sauci)
C	Combat Information/detection reporting (W,X,Y,Z) (CID)
C	Combat Air Patrol Coordination (W,X,Y,Z) (CA/AC)
C	AAW Gunfire/Missile Coordination
O	SAU-Air Control (A,B,C,D)
C	Shore Fire Control (A,B,C) (SFC Spotting)
O	LINK 11 (THIS IS A COMPUTER-TO-COMPUTER LINK)
O	Military Air Emergency
O	International Air Emergency

Several enlisted personnel are detailed specifically to receive, display, deliver, and/or transmit CIC communications. Sound Powered Phone Talkers monitor their assigned circuits and orally relay interior messages to their appropriate destinations. The Dead Reckoning Tracer (DRT) Plotter operates the DRT and maintains the surface plot. The Communications Message Handler operates the pneumatic tube to transmit and receive written messages, and distributes and files such messages. Radio/Tactical (R/T) Talkers and Recorders monitor their assigned circuits, and relay, record, deliver, and transmit external messages.

2. Development of SPRUANCE CIC

a. Design Strategy

Development of the design specifications for the SPRUANCE Class ships currently under construction began in

1967. Correspondingly, design specifications for the future AEGIS destroyers are based on the technology of the late seventy's. Because of bureaucratic and fiscal constraints, it is simply not feasible to build a current, "state of the art" Naval ship. For example, the large screen displays (LSD) that were available when the SPRUANCE was in the design phase were too large and unreliable and it was not technically feasible to place them aboard ships of destroyer size. Acceptable LSD's are available now, but placing them aboard the SPRUANCE destroyers currently under construction would involve modification of existing shipbuilding contracts. The Navy has been the target of much criticism regarding extensive changes to such contracts, and the resultant settlement negotiations often require a great expenditure of time and resources. Therefore known modifications are often delayed until the ship is overhauled. (As will be seen in Chapter IV, LSD's are scheduled to be placed aboard the future AEGIS ships.)

The Litton report shows the space arrangement and gives the rationale for the 1971 CIC mockup, including diagrams of functional areas, major items of equipment, and personnel operating stations. Room arrangement was based on the organizational structure of CIC when the ship is in its highest readiness condition. The planning assumptions regarding the duties and responsibilities of CIC personnel also affect software design, but do not usurp the commander's authority to assign personnel, as indicated in the following passage (12:6-4 - 6-15):

"In designing the DD 962 (SPRUANCE) ship operational program software, operator entry capabilities and console display formats are allocated in accordance with the expected functions to be performed by operators in these various modes. This is in no way meant to direct or limit the Commanding Officer's prerogative with respect to whom he assigns to operate a console or in which mode he desires that person to operate. It does, however, assume that the console mode name is descriptive, or at least implicative of the functions performed by associated operators from a total system operation standpoint."

A good deal of the rationale used in designing the equipment arrangement was the result of a careful examination of necessary interpersonal and man-machine interactions within CIC. The operational sequence of various tasks was analyzed, as were CIC personnel and equipment performance in functions typical of the mission and tasks of a SPRUANCE Class ship. These analyses led to the development of a chart which illustrated required visual, verbal, and tactile interpersonnel relations as well as those between men and equipment. From these data an Adjacency Diagram was created which was subsequently used in arriving at an optimal arrangement. This diagram determined, for example, that for critical operations the Evaluator, and presumably the Commander, if present, must be adjacent to the Operations Summary Console. The Weapons Coordinator, Operations Coordinator, and the ASW Control Officer should be within twelve feet of the Captain's chair, and the DRT operator and the DRT, Mk-116, and surface warfare coordination consoles are to be in direct line-of-sight of this chair.

The overall CIC arrangement of spaces and equipment was also configured to allow efficient traffic flow during normal operations. The bridge--CIC ladder, for example, was positioned in the center of each in order to allow for the most rapid possible traffic flow between the two spaces. A short sample of the arrangement rationale in the Litton report follows (12:6-43):

> "The Dead Reckoning Tracer (DRT) has been placed in the Command area, near to the Mk-86 consoles to fulfill either a normal plotting function (or) a fall-back plotting function in the event of console/computer failure and a shore bombardment role.
>
> The communications station for the R/T recorders has been placed near the Command and Decision area center, but where they will have little adverse effect on the central operating positions. The pneumatic tube and Link 14 have been placed at either end of this four position desk. The two 60 inch plot boards have been designed to stow in an overhead position in case they are not required.
>
> The Command and Decision area, therefore, has both flexibility and more than adequate adjacency with all other functional areas of CIC."

b. CIC Mockup

Litton constructed a "soft" CIC mockup which utilized models which resembled actual equipments only in size and shape. Photographs of control panels were placed on key items of equipment in order to show important man-machine interfaces. When possible, the equipment and space for the CIC were modeled in accordance with contract specifications for the actual equipment and space. All major items of equipment were indicated in the mockup, including mundane yet necessary large items such

as a file cabinet and a cleaning gear locker. In addition, weight and space reservations were made in "phantom" form for certain specific future equipment, such as electromagnetic surveillance and counter-measures gear, in anticipation of conversion and modification.

It has already become necessary to modify and in some cases rearrange the SPRUANCE's CIC in order to accommodate the installation of a number of new and advanced sensor, display, and weapons equipments. These include the NATO SEASPARROW Missile System (NSSMS), the Acoustic Warfare System, TOMAHAWK, HARPOON, the Target Acquisition System, the Close In Weapon System, and LAMPS III. Large blocks of equipment in CIC were palletized and installed in CIC as units. It is therefore generally possible to install the necessary components of these new systems in a functionally logical manner, employing the principles of human engineering, and without disturbing the existing structural arrangement. A brief synopsis of the modification for two of these improvements is included here for illustration:

NSSNS. In the early stages of the design of the SPRUANCE, an area along the starboard bulkhead, just forward of the status boards and vertical plotting boards, was "space and weight reserved" for this system. Norfolk Naval Shipyard recently installed the NSSMS in this area aboard the SPRUANCE. This location is logical for it is in full view from the Captain's chair.

LAMPS III. Two pieces of LAMPS III equipment are to be installed in the SPRUANCE CIC. The OJ-200/UYA-4(V) Monitor Control Console is functionally related to the electronic warfare equipment and is therefore located in that section in a "space and weight reserved" area. The Data Link Remote Control Panel ensures the strongest possible data link signal with the LAMPS by controlling the direction of the antenna. This panel is controlled and located by the helicopter tracker and is placed above his current console.

C. BRIDGE

1. Description

The bridge consists of the enclosed pilot house and port and starboard bridge wings. The pilot house has windows on three sides and part of the fourth to provide maximum visibility, and these windows are slanted outboard to reduce glare. A display strategy similar to that used in arranging CIC was utilized in constructing a mockup of the bridge. Like CIC and other parts of the ship, the work consoles were designed so that operators would have everything they need at their fingertips. To quote again from the Litton report (12:6-24):

> "The Bridge has the primary responsibility for safety of the ship. This includes utilization of navigational sensors in connection with ship control during independent steaming, stationkeeping, rendezvous, underway replenishment, tactical maneuvers and piloting."

Another part of the report lists the following bridge functions (11:6-1 - 6-2):

"A. Control ship's speed, course, and maneuvers under normal conditions

B. Exercise command over entire ship

C. Exercise tactical control of ownship

D. Provide piloting facilities and information to the Conning Officer

E. Perform record keeping tasks

F. Conduct interior and exterior communications necessary to accomplish other functions

G. Provide visual surveillance required by international law."

2. Key Personnel

The role of the OOD, and the frequent presence on the bridge of the Commanding Officer, has already been discussed. Other personnel necessary for various condition watches include Junior Officer of the Deck, Boatswain's Mate, quartermaster, ship control console operator and his standby/assistant, navigator's assistant, lookouts, and interior and exterior "talkers."

3. Displays

As stated in the Litton report, the UYA-4 Console (11:2-2):

"Is the basic display console for the Command and Decision Subsystem. Eight units are located in the Combat Information Center (CIC) and one in the pilot house. ... (The) console in the pilot house provides an operator with a 12-inch diameter range-azimuth cathode ray tube (CRT) presentation. A reflection plotter assembly is included which shields external light and permits the operator to plot the movement of contacts.

Ownship radar and sonar contacts may be displayed. If desired, the console operator also may choose to display symbology that is representative of the contacts of other Link 11 Tactical Data Link users. The pilot house UYA-4 console will be the primary device used to enter ownship navigational information and the Command and Decision Subsystem

(i.e. computer). In addition it is anticipated that the pilot house UYA-4 console could be used to strengthen the command interaction between principal officers in CIC and the pilot house during advanced battle readiness conditions. Without this console the pilot house personnel must rely on normal interior communications and one AN/SPA-25 radar repeater. With this console the two individuals conversing (e.g., Evaluator and Commanding Officer or OOD) may view identical or related CRT displayed information as they converse."

It should again be emphasized that the bridge is primarily responsible for the safety and navigation of the ship. It is more concerned with avoiding collisions and less concerned with the air threat. Therefore the air situation, which is the specialty of NTDS, is "nice to know" information for the bridge, but the more static surface display is critical.

Several other displays are also available on the bridge. To quote from the Litton report (11:6-12):

> "The UYA-4 console will be a prime source of information for the Commanding Officer when he is on the bridge. Accordingly the console has been placed on the starboard side of the pilot house in what might be described as the bridge tactical area. This area will also include the tactical table, the plotting/status boards, and the Weapons Status and Approval Panel (WSAP). The WSAP has been mounted where it is easily visible from the UYA-4 console because it may be desirable to use both at the same time."

The report explains the WSAP as follows (11:6-6):

> "The pilot house WSAP unit is one of two on the ship. The second is in CIC. Only one is activated at a time. The WSAP is used by the Commanding Officer to grant approval as to the type of ASROC payload (torpedo or depth charge) to be used in an impending attack. The type of payload is recommended by and approval is granted to the ASW Control Officer in CIC. The WSAP provides the following status indicators:

1. Torpedo Selected/Approved
2. Depth charge selected/approved
3. Panel enabled
4. Panel cleared/reset.

Each WSAP is hardwired to the Mk 116 Weapon Control Panel of the ASW Control Officer. Manual manipulation of an enabling key is required to actuate the panel. Without (the) approval (of the key holder, normally the Commanding Officer), the firing circuit concerned cannot be electrically completed."

Brief mention should be made of four other bridge displays which aid in control of the ship. The Ship Control Console provides a centralized and integrated location for direct control of the ship's heading and speed. The Engine Order Dual Indicator consists of a row of lights for each shaft which indicate standard orders commanded. The RPM and Pitch Display Indicator is a bank of eight digital indicators, one each for actual RPM, set RPM, actual pitch, and set pitch for both the port and starboard shafts. The Sonar Sounding Set (Fathometer) indicates water depths both on a digital numeric display and on a permanent strip chart recorder. Although the fathometer is traditionally located in the chart room, on the SPRUANCE the pilot house was chosen as a better location so as to provide the navigator with depth information when the ship is in shallow water.

4. Communications

Most communications facilities available on the bridge are also available in CIC, and were so notated in Table I. Additional circuits include the light machine gun control circuit, a dial telephone system for outgoing calls, three voice tubes to connect the bridge wings to the pilot house and

to connect the pilot house to the Captain's Sea Cabin, and a transceiver for ready interchange of voice traffic with passing merchant ships.

This chapter has examined in some detail the command control configuration of a typical ship. Chapter III will discuss some controversial issues in afloat command control.

III. ISSUES

Several issues keep recurring during seminars and discussions on command control. Five of these issues and corollary questions, as they pertain to command control afloat, are discussed in this chapter:

The Role of the Afloat Commander

Where is the Commander in a Crisis?

Attributes of the Computer-Commander Interface

The Commander-Computer Interface

Manual Backup Capabilities.

A. THE ROLE OF THE AFLOAT COMMANDER

1. President-to-Foxhole Communications

One of the most common topics to arise in discussions about command control is that of "President-to-Foxhole Communications." This is a modern phenomenon, made possible and perhaps inevitable by modern communications technology. The phrase is self explanatory: it is possible to provide the Commander-in-Chief with direct communications to any individual element of the Armed Forces. Such direct communication, however, is an extreme deviation from one of the military's most basic precepts: that of the chain of command.

Opponents of "President-to-Foxhole" communications cite the 1962 Cuban Missile Crisis as an example of high level "interference" which turned Commanding Officers into mere "marionettes." These opponents claim that such officious

meddling "degraded performance," and that the Captains had enough to do (maneuvering their ships, preparing boarding parties, etc.) without being bothered by Washington. These opponents are not arguing against civilian control of the military but only against civilians making long distance tactical decisions. Their views might be summarized as "Give us the orders and let us carry them out as we think best. Well, perhaps we should allow the President to send one-line orders, but we certainly can't have every staff aid choking our communications with inane chatter." Opponents further note that cutting all the intermediate links in the chain of command leaves too many intermediate commanders completely in the dark, and that these intermediate commanders need to know what is happening in order for them to provide necessary tactical and logistical support. A related question that these opponents ask is, "Are we creating a generation of "commanders" who have never made a decision of their own?" They cite several recent instances of "passing the buck." For example, during the 1976 Lebanon evacuation, a boat officer did not know whether or not to allow a child to bring his pet dog aboard, so he asked the ship. The Captain "couldn't" make the decision either -- so Washington was consulted! If sea-going "decision makers" become this dependent on high-level help, what will happen if Washington is bogged down in more than one crisis, or if communications are poor? Who will make the decisions then?

Proponents of creating President-to-Foxhole communications links cite the Cuban Missile Crisis to support their views also. When the US and USSR were "eyeball to eyeball," the President had both the right and the responsibility to be directly involved. Whether or not to pull the trigger and quite possibly start a nuclear war was and is a decision that belongs to the President. Once the bombs start falling, then the military takes over the tactical situation. As stated in a 1976 U.S. Naval Institute Proceedings article by Vice Admiral Ray Peet and Dr. Michael E. Melich (15:29):

> "The appearance of nuclear weapons... had had an effect on the structure of naval forces and the way they are commanded, even when nuclear weapons are not being used.... This new mission capability, starting about 1952, saw the nuclear strike force onboard the attack carrier linked to the President so that the order to strike could be given expeditiously. This placed new demands on the multi-layered command and control structure used to execute conventional attacks and placed a premium on reliable communications. It also meant for the first time that the fate of the entire nation could be decided by the actions of a small group of men at sea with enormously powerful weapons. Under these new circumstances the actions of a single naval vessel at sea could become of paramount importance to the highest authorities of the nation. No longer was the ship at sea in splendid isolation, as she had been in days before sophisticated communications and weapons of awesome power. The individual ship had become too powerful."

Except in special cases, such as the Cuban Missile Crisis or the more recent MAYAQUEZ incident, the President does not get involved with the military's day-to-day operations -- he clearly has enough other duties to keep him occupied. The military is required to keep the civilian decision makers as well informed as possible, and better command

control communications will likely lead to more civilian control. The military simply has to accept this inevitable by-product of detailed, real time information systems.

Afloat Commanders are learning that they can actually be aided by shore advice. In the Peet and Melich article, in referring to national intelligence assets not under the control of the afloat commander, they state that these national assets produce large volumes of data which need further processing to be usable. (15:29) Such assets may actually provide better indication of the task force's environment than the forces own systems, which may provide ambiguous or contradictory information.

Orders from ashore may also originate within the Navy, as Peet and Melich state (15:33):

> "Sailors have a horror of someone behind the desk telling them what to do with their rudders. Rarely, if ever, would a fleet commander-in-chief (overall tactical commander-in-chief of several task forces) issue tactical signals to units at sea. We can visualize, however, that the deputy fleet commander-in-chief or task force commander may order a unit commander to change his emission control condition or launch his electronic warfare aircraft because the fleet command center would have better information on which to base such a decision. Messages emanating from a fleet command center would for the most part be advisory in nature, telling the commander at sea the source and credibility of the information being provided, and permitting him to override the advice, if in his opinion, his observation and close-in sensors tell him he should do so to save his forces. Of course, with the fleet commander-in-chief in the command center, we are sure the at-sea commander will consider the source of the advice and the fleet commander-in-chief, in turn, should be aware he assumes a direct responsibility for the quality of the advice."

In general, the command structure should not be circumvented. Intermediate commanders should at least be kept fully informed of the information and orders being passed even if in some unusual situation it is felt that there is no time to consult them. It should be understood within the chain of command what sort of decisions should or must be made at what level of command. This "appropriate level" is usually determined by "who has the necessary information," by the possible implications of a "bad" decision, and by general bureaucratic maneuvering.

2. States of Crisis

"States of Crises" are usually divided into levels such as:

Day to day operations

Crises

Conventional war

Theatre Nuclear war

General war

Reconstitution

Restrike

Recovery

In such a continuum, the differentiation between strategy and tactics is blurred and perhaps only semantic. "Strategy" is of larger, national scope and is less structured, involving large scale, long-range planning and development. "Tactics" deals with more immediate battle maneuvers. A strategic decision may have to be made in days or even hours, but a tactical

decision such as targetting may have to be made in minutes or less. Commanders are generally strategic planners but may become operational controllers in a crisis, and "command control" must change its basic character depending on the level of conflict. However, there must be a smooth transition and continuity of operations between the states of crises.

The course of any particular crisis might be summarized as follows: (10:9-11)

Event occurs

Detection

Recognition

Response Formulated

Response Initiated

Response Implemented or Preempted

This thesis is most concerned with the time necessary for response formulation and in particular the displaying of a perceived threat to the Commander. It should be noted that most of the response delay to this point is not caused by speed-of-light communications but by slow human procedures: in a time critical situation, man-machine and interpersonal interaction times are also critical. It should be noted that most "crises" communications channels are also used in day-to-day operations. A Commander commonly spends only about five percent of his time in "threat exercises" and the majority of his time is spent on supervising his staff and on other routine details necessary to maintain the Navy.

3. The Role of the Staff

The Commander obviously does not do everything himself but instead delegates routine decisions to his staff. He establishes general policy and is notified by the staff whenever anything unusual arises. Of course, each Commander organizes his staff and his information system according to his own management style. However, his general role is to establish policy for the use of his resources but make all critical decisions himself.

Since Commanders are busy people, it is difficult to get their close involvement in systems planning. It is the staff who usually meets with the designers of command and control systems; it is the staff who usually sets the detailed requirements such as, "how long should a history track be maintained?" Does the staff want the same capabilities in a computerized information, retrieval and display system that the Commander wants? In many cases, no. The staff is frequently interested in static data. Some information storage experts feel that such encyclopedic and historic data can be better maintained on microfiche. For example, when the Commander wants real time information on the current tactical situation, a computer could display the location and identity of all nearby platforms while the staff might be tasked with supplying any necessary static details. There must be some flexibility built into any command control system -- it must allow a

command to make some small modifications; it must be somewhat responsive to the Commander's personal mode of operation. Sucn systems must have commonality and interoperability, but it is not feasible to impose standard inflexible command control systems and arbitrarily expect commanders to use and support them. (When used in this context, "standard" means identical, but "commonality" implies an interoperable system with options.)

B. WHERE IS THE COMMANDER IN A CRISIS?

Since World War II there has been some disagreement over the Commanding Officer's Battle Station. In a crisis, does he belong on the Bridge or in CIC? This section will present the views of various experts.

Rear Admiral Daniel V. Gallery's Naval career included service in carriers, battleships, cruisers, and destroyers. An aviator, he invented several improvements in aircraft machine gun sights and was closely associated with the development of the Norden bomb sight. On 4 June 1944, while Captain of the jeep aircraft carrier USS GUADALCANAL, this unusual and imaginative man made naval history with the boarding and capture at sea of an enemy naval vessel, a German submarine. This was the first such action by the United States since 1815. This imaginative officer described this and other experiences in his 1945 book Clear the Decks! In this book he stated (8:153):

> "In the past, whenever anything unusual happened at sea, the Captain hurried up to the bridge to have a looksee. Now, many Captains head for C.I.C., instead of the bridge, because you can actually "see" more there. The large vertical plotting board in C.I.C. shows the present position of all planes in the air, whether they are friendly, hostile, or unidentified; of other

> ships; of land; and a great deal of other information. It is continuously corrected up to the minute as the radar antenna sweeps around the horizon.
>
> You can glance at a radar scope and "see" another ship twenty miles away on a dark and foggy night. If you were straining your eyes through the fog on the bridge, you might not SEE this ship until just before you collided with it. By radar you can "see" an approaching enemy bomber a hundred miles away while there is still time to organize a reception committee if you work fast. But if you wait till you see him with your eyes, it's too late to do anything but lead out the fire hoses and alert the stretcher bearers. However, custom dies hard, and some of the current generation of skippers still stick to the bridge. As radar and television improve, what you see with your eyes becomes less and less important. The Captains of the atomic age will pace the deck in C.I.C. instead of the bridge when the heat is on."

Thirty four years later, however, the "current generation of skippers" is STILL being told to "stick to the bridge," as is evidenced by the following passage from the third edition of the U.S. Naval Institute book, Command at Sea (4:204):

> "Regulations do not specify the station assigned to the commanding officer in battle anymore than they do for other special evolutions such as navigating in a fog or coming alongside. Naturally, he must be in the position where he can best do his duty which in this case is to fight the ship. From time to time, it is argued that the commanding officer could better control his ship from CIC for certain evolutions and one may suppose that for long-range, surface-to-air actions with guided missiles, the bridge might not be the most effective place for the captain. When shooting and maneuvering, however, general opinion in the Navy is that the captain should be on the bridge where he can see and hear for himself.
>
> In the conning tower, visibility is necessarily limited; on the flying or navigation bridge, the commanding officer can see sky, sea, and horizon. During a night action he has to be

in the best position to see for himself that he is in no danger of running into the ship ahead, or that some other ship will not collide with him. In destroyers and smaller ships, the bridge is always the battle station for the captain."

Discussions by this author with various members of the Naval establishment, including several Rear Admirals, reveals a continued divergence of opinion on this "bridge versus CIC" question. This issue is critical to the whole topic of afloat command control -- obviously "command control" displays must be located where the Commander can view them or, as stated in the introduction, they simply are not "command control" displays. Presumably all interested parties will agree that wherever a Commander is located in a crisis, there must be adequate communications and supporting staff and that he should be located wherever he can best be kept abreast of the situation. Yet there remains an "Old Guard" who avoids CIC -- such as the captain of a nuclear combatant who visited CIC only once during a recent two week exercise -- and that was to accompany a visiting Admiral on a tour. Some ship designers have been suggested that all displays be removed from the bridge in order to "force" such Commanders into CIC, but it is simply not feasible to "divorce" the bridge from the rest of the ship. The best inter and intra ship communications and the most information are found in CIC. Because of space, lighting, and security problems it is also not feasible to move all of these capabilities to the bridge. There are occasions when the Captain does belong on the bridge, especially during the risky navigation required in maneuvers with other ships or in picking up a man in the

water. Even when the Captain is in CIC during a critical situation, the Executive Officer should be on the bridge. It must be noted that in many situations tradition and law require the Captain's presence on the bridge. Just as important, many Commanders simply like to be on the bridge. While it is commonly understood throughout the Navy that the Commander's primary responsibility in peacetime is the safety of his ship, it should also be understood that in wartime his primary responsibility is to fight his ship. Just as there are situations that require the Commander's presence on the bridge, there are also situations that require his presence in CIC, for that is where the sensor terminals and weapons controls are located. Like the junior officers, he must be comfortable and experienced both on the bridge and in CIC. Only through familiarity with all of his command control facilities will the commander be able to optimize their use in a crisis, and in a crisis, he should be wherever he can best fulfill the mission.

Since the Commander WILL be on the bridge during some critical situations, there must be some sort of command control display available on the bridge that will give him complete, prompt, and accurate information. Thus a data link between CIC and the bridge is necessary. On the bridges of some ships, such as the SPRUANCE class destroyers, a computer console type of display is installed; on others, the display consists of a television monitor of the NTDS display in CIC. In any case, the display must be adaptable to the changing light conditions found on the bridge.

C. ATTRIBUTES OF THE COMPUTER-COMMANDER INTERFACE

This thesis has repeatedly mentioned "command control displays," but has so far made little mention of the nature of the display itself. The display should be graphical, not just verbal. "A picture is worth a thousand words," or as Dr. J. S. Lawson states (10:4):

> "In a typical situation, there will be at least 20 to 100 objects about which the commander must be informed. For each of these objects, it can be shown that he will need an absolute minimum of about 300 bits of data before he can be an effective transducer of information into decisions and directives. And the most important part of this information deals with the special relationships between and among the objects, which have to be derived trigonometrically from the data.
>
> Studies have shown that the human brain can only process 25 to 40 bits of information per second when they are presented as a time sequential stream such as a printed message. This implies that it would take the commander at least 15 minutes to understand what was going on. Yet our common experience tells us that we can easily process three million bits per second when they are presented as a two-dimensional picture -- (e.g., a TV screen or a map).
>
> Thus we have no alternative but to present the commander with a picture -- a geographic display -- so that he can absorb the large number of special relationships among the things with which he must deal. Moreover, on a geoplot we can express much of the "data" by the size, color, etc. of the same symbols we use to mark the location of things.
>
> So, besides the commander himself, acting as a transducer, the most crucial element of a command control process is that it provide the commander with a geographic display of where things are. And by direct inference, three important measures of efficiency and the process are the locational accuracy, the informational accuracy and the timeliness of the picture which is presented."

The following table of display related attributes is not a list of "necessary" features or even "useful" features, but merely an incomplete list of features that may help to convey information to a Commander. Such lists could be helpful in establishing tradeoffs and improving the interface between technological developers, fiscal planners, and operational users. For example, color displays seem to be more appealing to the theorists, scientists, and engineers ashore than to the users at sea who do not see the benefits justifying the cost. (Currently color is "dead" in the Navy -- although systems may be designed for future color conversion, no color display systems are currently being accepted for afloat displays).

TABLE II

SUGGESTED ATTRIBUTES OF COMMAND CONTROL DISPLAY SYSTEMS

Accurate
Affordable
Anti-jam
Capable of voice, data, and image transmission
Commonality (adaptable to user, vice strict standardization)
Constantly updated
Credible
Designed with human factors considerations
Digital
Easy to Maintain
Efficient
Of "Fail Soft" design, with reduced capability programs
Flexible (accommodates unforeseen situations)
Interoperable (with other command control systems)
Real Time
Redundant
Reliable

Rugged

Secure

Timely

<u>Attributes the display itself might have include</u>:

Clarity

Color

Conferencing capabilities (with interior and external stations)

Correlation capabilities

Decision aiding and predictive capabilities

Graphics

Hard copy backup (for reviewing exercises, etc.)

Interactive capabilities

Large area and zoom displays

Large screen displays

Message readouts (although some Naval officers claim that messages are not "real time" information and that a pneumatic tube from "radio" is quite adequate)

Simple user interface ("natural," reactive interface that accommodates a variety of users)

"Three dimensional" displays showing the air, surface, and subsurface situations.

Information requirements vary with the situation. Several studies have been conducted to discern what information the Commander requires, but there is still no definitive answer. It would be easy to say, "Give him everything he wants," but Commanders are individuals who want different information. Types of information displayed might include:

Track, location and identification data

Track histories and situation updates

Capability data of own force and other platforms

Threat information

Messages and announcements

Weather information

Satellite photographs with geographic references

Air plans, aircraft fuel status, and current aircraft aloft information

Maintenance and supply data

Daily call signs and other communications information

References for further information

As has been stated, the data in an afloat command control display system comes from sensors both afloat and ashore. The vast quantities of data being exchanged seem to demand computer to computer communications links between shore and ships and between ships. But many naval ships have no computer, and must rely on voice and teletype links for all communications. In addition, the shipboard terminals on major combatants are not configured to accept and process information transferred in the "packet switching mode," which is the mode planned for use in the next decade. Some of the current thought about this area is indicated in the following comments by Mr. C. C. Stout (17):

> "For the past three or four months a new idea has begun to emerge. It is rather simple yet has a number of ramifications. The idea stems from a variety of sources. It relates to my concepts of Navy's NCCS (Navy Command Control System) as a truly integrated system. The easiest way to describe it is perhaps as a missing computer to computer link. That link is one between ships at sea and shore centers.
>
> At the moment (the) Navy has shore data bases at the FCC's (Fleet Command Center) which are not trusted. I am sure that part of the reason is (that) much of the input data comes from ordinary run of the mill ships which generate data in a manual mode. (The) Navy has

either not been willing to spend the few thousand dollars per ship needed for a simple "format" generator or just doesn't understand why it should spend such dollars. Perhaps it would help if someone in a position of real authority in OPNAV would stop for a moment and think about the implications. On a daily basis information is being generated and put into the data bases which are supposed to serve as the information sinks for our most senior decision makers. The kinds of decisions they must make when the "chips are down" require good information. That alone should be adequate justification for a shipboard C2 terminal. This might be a good thing to price out. I think it would be interesting to see how much it would cost to provide good data using a "ship terminal" and then compare that price with what has been spent on the FCC's.

> At the moment only 21 Navy ships can receive and "machine process" intelligence products generated ashore. This is a fairly serious deficiency in that the vast majority of ships do not have (the) tools to display, in a timely manner, the threat within the range of weapons such as TOMAHAWK. This also seems to me to be adequate reason all by itself for a shipboard C2 terminal."

It is possible to provide an incredible quantity and variety of data, but capturing and retaining great amounts of unnecessary data will saturate a shipboard communications and storage system. The ship must have a self-contained database, but the question of "how large" a shipboard database should be is beyond the scope of this thesis. It is important, however, to note the paramount role of the database to any command control display. What a Commander "needs to know" is therefore a topic requiring more in depth research.

D. THE COMMANDER-COMPUTER INTERFACE

Thus far in this thesis the Commander's role in command display systems has been that of passive observer. The sugges-

tion that a Commander might personally operate a computer terminal is strongly opposed by many Naval Officers. Regardless of the cause of this rejection of a direct "Commander-computer interface" -- bad experiences, lack of understanding, unfamiliarity with real time interactive computer systems, or other reasons -- the rejection does exist and must be considered in any examination of command control displays. These opponents are not necessarily anti-computer. They do feel, however, that the Commander should not be tied to a terminal, and especially not during a crisis. These officers feel that when a Commander wants information he should interface with a person who is capable of "talking" to the computer in the proper format. (For the purposes of this thesis, this person who is the link between the Commander and the computer is called an "interfacer." This job is analogous to that of the Sound Powered Phone Talker, who is the enlisted man who speaks for the Commander on the ship's interior phones. For example, a Captain may say, "Tell Combat I want a report on that Boggie" and expect it to be formatted into "Combat, Bridge. Give me a report on Boggie 3." To protect against errors, the OOD is often required to monitor the phone system).

The attitude of those who think it unlikely that commanders will ever operate computer terminals might best be exemplified by the Rear Admiral who stated, "I manage people -- I don't operate machines." Yet another Rear Admiral pointed out that his major task is NOT to manage people, that that is the function of his Chief of Staff. He also pointed out that Commanders

DO operate some machines: they type or dictate memorandums and operate telephones, for example. There are obvious inefficiencies in utilizing an "interfacer," for both time and manpower would be saved if this middle man were eliminated.

It appears that a major reason for rejection of a direct Commander-computer interface is that many of today's commanders are unfamiliar with computers in general and with real time interactive terminals in particular. Commanders of the future will be more familiar with computers, but it is totally unreasonable to demand that all Commanders become computer experts. Because the computer is essential to modern warfare it IS reasonable, however, to expect the Commander to be an "educated user." At the very least, he must know the basic capabilities and limitations of the computer system and understand its display symbology. His staff, of course, must include computer "experts" -- people who know how to extract the desired information and people who can repair hardware and software malfunctions when the nearest computer manufacturer is thousands of miles away. Even if the commander IS the "operator," it would probably be necessary to have an "interfacer" to ask unusual questions efficiently. With a good staff to assist him, it is not necessary for the Commander to be a computer expert.

As in any area of computer design, it is important to know the desires of the user. As mentioned earlier, a Commander is an individual with a unique management style. He cannot be dictated to in his choice of system options. If the system

is not designed specifically for him and tailored to him, the Commander simply will not use it. The operational experts who set the requirements for new systems understand this, and thus a "standard" Commander's terminal is not likely to receive budgetary consideration.

Again the word "commonality" is appropriate: the system must be interoperable but have a choice of options, thus making it adaptable to different users and different situations. Among features which should be considered to assist the Commander-user are function keys, natural language, and user-defined abbreviations. Function keys can be used to key commonly asked questions, such as "where is ---" or "what is--- ." Natural languages would allow the Commander to "talk" to the computer in his own, i.e., English, language. User defined abbreviations would save the Commander typing time. For example, the user might want "CON" to be defined as "USS CONSTELLATION." All of these options are available in existing software programs, and they make operating a terminal fairly easy even for novice users. Since such programs can be tailored to each individual user, the entire staff would not have to learn the code when any one user wanted a new definition.

E. MANUAL BACKUP -- HOW MUCH IS ENOUGH?

Once it has been established that the computer is indispensable to the modern Commander, the question must arise: What happens when the computer breaks down?

One school of thought claims that manual backup is simply not necessary and that retaining any usage of grease pencils

is an archaism from World War II that wastes scarce personnel assets. This school stresses the importance of computer redundancy, recovery, and protection from any data loss. They place emphasis on automation of remaining manual functions with such technically feasible equipment as automatic tracking (in stead of NTDS's manual ball-tab-response), automatic status boards (ASTAB), and mechanized slide making. After all, these advocates point out, a "modern" war cannot be fought without computers. As one operations officer on an NTDS equipped ship said to this author, "If we lose our computers, the battle is over for us anyway. We can't detect attacks or defend ourselves against them. All we can do is make steam and get underway -- otherwise we're simply a hazard to navigation."

At the other extreme are those who have not quite accepted the computer, who insist that some manual backup will always be necessary -- to check the computer, if for no other reason. As the saying goes, "the dipstick is never wrong." A further sample of their logic is found in the Watch Officer's Guide (18:178-179):

> "There is a deplorable tendency among many officers to spend their watch with their noses glued to the radar scope. While this invaluable device must often be used, it must not be to the exclusion of visual observation and the intelligent use of well-trained lookouts.... An important, and sometimes much neglected aid to safe ship operation is the lookout. The trained human eye is still superior in many respects to the most elaborate machine."

In addition to custom and utility, law requires the use of these manual backups, as pointed out in the following excerpt from All Hands (5:41-42):

> "Around the clock on the nuclear-powered aircraft carrier USS NIMITZ (CVN 68), lookouts scan the sky and ocean for anything that could pose a danger to the ship. Everything from driftwood to aircraft, from ships to oil slicks, is reported.
>
> Lookouts are not just an archaic convenience -- they are required by Rule 5 of the International Regulations for Preventing Collisions at Sea. The rule states: "Every vessel shall at all times maintain a proper lookout by sight and hearing, so as to make a full appraisal of the risk of collision."

Advocates of manual backups point out that the mighty grease pencil and plotting board are invaluable when, for some reason, NTDS is lost. They also point out that even the awesome NIMITZ Class carriers maintain paper message files because the computerized Message Processing and Distribution System (MTDS) has experienced an "unacceptable" amount of downtime. In 1972, the carrier FORRESTAL suffered a major fire which included destruction of her NTDS. A Captain who was aboard her at that time told this author that with all her CIC automated systems inoperable, she was a beautiful and operational ship -- without a brain. Such catastrophic failures are probable in war, and if the loss of one or two systems renders a ship totally helpless, then there IS too much reliance on machines, too much dependence on technology.

How much manual backup is enough? Of prime importance is the absolute necessity to employ systems which "fail soft" -- the system MUST degrade gracefully; that is, it must not be so fragile that small problems could render the entire system inoperable. Even if the system is not working perfectly, critical information should still be available. It is therefore

necessary to differentiate between "nice to know" information and that information vital for continued military action in a crisis. This latter information must still be available when the system is in a fallback mode, when it is saturated, and even in the event of system collapse. There is also a place for some manual status boards on even the most modern ships: boards for auxiliary information that is referred to frequently by several people and which changes infrequently. The daily call signs of ships, for example, would be much more convenient on a group status board than on an individual ASTAB, especially if an existing display must be replaced in order to recall such static information. When written in phosphorescent chalk, this information is available even if lighting is not available. The final chapter of this thesis will discuss a future afloat command control system.

IV. PLANS AND POSSIBILITIES

Thus far this thesis has discussed current afloat command control systems and some of the issues surrounding them. This chapter will discuss a major new system currently in the planning stage and will close with some final comments regarding the computer-Commander interface.

A. AEGIS

The Aegis Combat System is a computer controlled weapon system. It will be placed on board the planned but as yet unnamed guided missile destroyer DDG-47. For the purpose of this thesis, "Aegis" will refer to the combat system and "AEGIS" will refer to the ship. The multi-mission AEGIS will utilize the SPRUANCE hull and propulsion system and will have most of the same weapons, including two 5-in./54 cal. guns with the MK-86 Gun Fire Control System, Tomahawk, ASROCS, Harpoon, Phalanx, and LAMPS. It is the Aegis Weapon System itself which will make the DDG-47 the first of a powerful new class of ships.

1. The Aegis Combat System

The heart of Aegis is the computer controlled AN/SPY-1A phased array radar. This powerful radar sends out energy beams in all directions and from ocean surface to stratosphere almost instantaneously, and provides extensive search and track capability for hundreds of short and long range targets simultaneously. Accurate enough for fire control all the way to missile impact, this radar system has midcourse command guidance communication with the Standard Missile 2 (SM-2). (2,16)

Aegis uses three computers, one for radar control, one for weapons control, and a third for command and decision. Other major elements of Aegis are the Standard Missile 2, the Guided Missile Launching System, the Fire Control System, the Operational Readiness Test System, the Weapons Control System, and the Command and Decision System (CDS). It is this latter system, of course, which is of most concern to this thesis. The CDS provides tactical decision support, operator/system interfaces, interfaces with other sources of tactical and intelligence data, a data link with other units, and coordination for functions such as air, surface, and submarine targeting.

To clarify terminology, it is emphasized that the Aegis WEAPON System consists of the elements listed above. This system could be put on any ship large enough to carry it, but the SPRUANCE hull has been selected for this task. Eventually it may be placed aboard some cruisers also. In contrast, the Aegis COMBAT system consists of ALL weapons and sensors on an Aegis equipped ship. Aegis is so powerful that it can coordinate the weapons of an entire task force.

2. History of Aegis Acquisition

As mentioned in Chapter II, it is not feasible to build a current "state of the art" Naval ship. The following chronology shows the long acquisition history of Aegis (2,14):

1963 -- Advanced Surface Missile System (ASMS) inaugurated. Formal expression of requirement made by the Chief of Naval Operations (CNO). Beginnings of concept formulation.

1964-5 -- Program Definition Phase. Seven leading industrial teams develop candidate systems.

1965 -- Naval Officers and engineers and personnel from military and industrial laboratories synthesize a basic system from the contractor suggested techniques and concepts.

1965-7 -- Secretary of Defense holds up development of system in order to increase its commonality with Patriot, the Army's air defense system.

1967 -- Complete commonality with Army found to be unacceptable; ASMS given go ahead.

1968 -- Three industrial teams selected for contract definition.

1969 -- Source selection process continues. Key measurable parameters developed. In December, ASMS becomes AEGIS and RCA is selected as prime contractor.

1970 -- Preliminary Design Review Completed. Naval training units established in four plants to work with the development engineering teams.

1971 -- Congress reduces number of AEGIS nuclear destroyers from 23 to five. Shipboard technical liaison program instituted to increase Aegis industrial personnel's awareness of at-sea equipment and user problems. Aegis moving from planning and study phase to design and fabrication stage.

1972 -- CNO authorizes new class of conventionally, vice nuclear, powered destroyers to be designed expressly for Aegis Critical Design Review. Major Aegis components completing their qualification test.

1973 -- The Secretary of the Navy directs that a gas turbine - powered DDG and a nuclear class ship be considered for AEGIS. System integration completed and determined to be ready for at sea testing.

1974 -- In May, Aegis is installed on the USS NORTON SOUND for at sea testing. By July, both the DDG and the nuclear destroyer are cancelled. In November, a Defense Systems Acquisition Review Council convenes to consider Aegis for a new nuclear cruiser.

1975 -- Navy and contractor testing and evaluation of Aegis continues on the NORTON SOUND. Secretary of Defense directs development of both gas turbine and nuclear powered AEGIS ships.

1976 -- Aegis testing continues on the NORTON SOUND. Secretary of Defense approves proceeding with adaptation of Aegis to the basic SPRUANCE hull and power plant.

1977 -- AEGIS Shipbuilding Project chartered, with one project officer responsible for both the Aegis Combat System and the AEGIS ship.

Present -- at the time of this thesis (February 1979), the fiscal year 1980 budget includes one AEGIS class destroyer for approximately 825 million dollars. The nuclear powered cruiser is currently not being considered.

Future -- AEGIS is scheduled to put to sea in another four years -- approximately twenty years after the original concept formulation. Since Aegis will have an estimated thirty year life span, the original planners were designing a system to be

used fifty years in the future! Such a twenty year procurement schedule is incongruous in a world with rapidly changing technology. Those who set operational requirements, those who design systems, and those who set fiscal policy MUST work together to eliminate unnecessary bureaucratic delay.

3. Design of the AEGIS CIC

The arrangement of CIC equipment for the AEGIS Destroyer is currently under study. The AEGIS CIC has the same space allocation as the SPRUANCE CIC, but with the addition of the Aegis Weapons System equipment, weight and space considerations become critical. The Johns Hopkins University's Applied Physics Laboratory (APL) has analyzed the command function (7) in order to define the requirements for a Tactical Command Module (TCM).

a. The Tactical Command Module

The TCM is currently planned to have two large screen displays, five small automated status boards, and three operator positions. A large screen display (LSD) has a 3-1/2 foot square screen and is five feet in depth in order to use rear projection techniques. The automated status boards (ASTAB's) are seventeen inch diagonal cathode ray tube (CRT) screens. The five ASTAB's are placed over the two LSD's, and the viewing distance for the whole display is considered to be optimal at about seven feet. The three operator positions are expected to be filled by the Commanding Officer, a "facilitater" to help maintain the displays, and a Tactical Action Officer (TAO) who will be in CIC full time and who will be in charge in the Commander's absence. Each of these positions has its own

console. Three consoles are envisioned to include CRT's with alphanumeric and possibly graphic capabilities; a keyboard to interface with the TCM computer; function keys, hook and ball tab, and other LSD/ASTAB picture controls; and a communications panel. Because of the AEGIS's task force weapons coordination role, a Task Force Commander's staff will probably be aboard in addition to the ship's own staff. Thus there will be two complete TCM's in the AEGIS CIC, for a total of four LSD's, 10 ASTAB's, and six console positions (7,6).

The displays are to include (6):

Simultaneous displays of all warfare areas

Monitors of the tactical situation, equipment readiness, and system status

Alerts of abnormal situations

Call-up of selected detailed data

Entry and Correlation of mission support information.

The detailed design for these TCM's is still under consideration. Some of the issues currently under discussion include:

COLOR -- Although some designers feel that color is necessary for a good LSD, according to interviews given to this author, the operational requirements part of the Navy does not consider color to be worthy of inclusion in afloat displays at this time. The AEGIS LSD equipment and software have limited, four color capacity, and this capability may be added later.

COMMANDER'S KEYBOARD -- Some senior Naval Officers consider this a total waste, as noted in the Commander-computer interface section of the last chapter. However, one of the objectives of the TCM is to improve the Commander's capability to understand and control the combat system operations (6). As stated in the APL Interim Report on Command Console Design (7:6):

> "In order to render a decision, an officer in command must first assimilate information pertinent to that decision.... The purpose of the TCM is to support the process of command level decision making by providing the requisite information and by providing paths through which to initiate actions.... The TCM will greatly enhance the ability of a decision maker to monitor and direct ... combat operations.... It is important to understand that TCM is a tool at the disposal of an officer in command and its level of use will be established at his discretion."

The report later states (7:11): "If he (the commander) should choose to exercise his prerogative to delegate, then he has confidence that the console is capable of satisfying any vested subset of his decision making requirements that might become vested in a subordinate."

DESK SPACE -- Although not all designers agree, it would appear that even in the computer age some space should be dedicated to a flat surface for hand written messages, printed material, and other assorted support material.

DETERMINATION OF PROXIMITY OF OTHER PERSONNEL -- Which other personnel need to be near the TCM? Should the others have small monitors of the main screens? Should the bridge? A careful analysis of interpersonal and man-machine functional relationships is required.

FUNCTION KEYS -- With variable function keys, a great many different operations can be performed in different modes. The optimum tradeoff between variety and simplicity should be studied. In addition, "natural language" programs should be studied to supplement function key usage by the Commander.

FACILITATOR'S ROLE -- Does he act as a computer expert? A super-yeoman? a "gopher?" His role is still ill-defined.

LARGE SCREEN DISPLAYS -- How will LSD's be used? A series of display formats appropriate for LSD's is now being developed (7). For years afloat personnel have asked for a clear, flexible, and reliable large screen display. Would it be better, for example, to have the Operations Summary Console (OSC) on an LSD, instead of having several people standing around it, which renders the Captain's chair practically useless owing to poor visibility? One suggestion is for large and small scale displays of the air situation and other displays for the more static surface and subsurface situations and for weather conditions and forecasts. Now that the technology is available, what IS the rationale for putting LSD's on ships? Because the Commander is more likely to use them than small screens where he feels like a mere operator? Because they enhance "group feeling?" The cost benefit value of LSD's has not been defined.

LOCATION OF THE TCM's -- As noted above, two TCM's are scheduled to be placed aboard the AEGIS, one for the ship's staff and one for the embarked Task Force Command staff. The layout relationship of the two TCM's becomes a driving factor in the

CIC equipment arrangement. If the embarked command staff were isolated in their own compartment, more sensitive information could be displayed there. However, if the two TCM's were located near or next to each other, the two staffs could more readily confer and they could share some supporting staff resources. Other considerations include area display visibility and shipboard space limitations. Regardless of design forethought, stanchions present positioning problems for final installation of equipment.

WHERE SHOULD THE TASK FORCE COMMANDER BE? -- The Navy is spending hundreds of millions of dollars to obtain Aegis, and the AEGIS ship is designed to coordinate the entire task force's weapons. The Task Force Commander will probably have a staff aboard AEGIS, but where will the Commander himself be? Since it is unlikely that a Task Force Commander will give up the prestige and habitability of a carrier for that of a mere destroyer, and since carriers will not have Aegis aboard, it is unlikely that the Commander will ever see the TCM. If LSD's are in fact being purchased for the Commander and not just his staff, then the TCM and the Task Force Commander should be on the same ship. Tactical Command should be where the best available personnel, equipment and communications are.

b. Analysis to Determine the Characteristics of the TCM

As mentioned above, Johns Hopkins APL is defining the requirements for the TCM. Reference 7 documents the design investigation that defined a "suitable" console for the

Commander. The report explains the functional analysis process as related to TCM related personnel and equipment and the resultant design analysis of the TCM staff. Phase I surveyed and recorded the specific tactical responsibilities applicable to the Commander and the TAO of an AEGIS ship. Through review of Naval literature, command responsibilities were enumerated and categorized in order to identify the functions pertinent to afloat tactical command. Phase II was a detailed function description of the command activity to be supported by a TCM. This functional description was then used to derive the information, display, and action requirements to be provided by TCM design. Phase III defined the displays and console components necessary to satisfy the requirements, which led to the definition of the TCM itself.

The report concludes with a few paragraphs on the continuing console investigation.

B. CLOSING COMMENTS

Much research is needed in the area of afloat command control. Among suggested research topics are:

1. What information is critical in various situations?

2. Commander's location in a crisis - what laws and traditions must be altered, and how can these changes be implemented, to enable the afloat Commander to be wherever he can best deal with a crisis?

3. Large Screen Displays - how can they best be utilized?

4. How does one justify the cost of enhanced command control systems? This question is applicable to all elements of afloat command control, of course. Two such areas mentioned in this thesis were color and LSD's.

5. How can senior naval personnel best be made familiar and comfortable with the role of computer user? More junior personnel should take the time now to become familiar with today's technology and hopefully to become more receptive to tomorrow's.

After examination of this topic, the author has concluded that the main problem in afloat command control is not financial or technological but the interface between financial planners, technical experts, and operational users. The systems acquisition process is far too unwieldy for the dynamics of technology. "Landlubber" designers tend to place too much emphasis on technique and not give enough consideration to operational conditions. Design teams must include experienced afloat commanders. It is, of course, difficult to obtain the services of such senior experienced personnel. It is also difficult to detail such personnel for necessary testing and training. Most important, afloat command control systems must be adaptable to various users and situations. As stated in an earlier quote from the Watch Officer's Guide (18:81-82), "The capabilities of CIC (or afloat command control in general!) are limited only by its equipment and the state of training of its personnel."

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